

Hyperon Enhancement in the Dual Parton Model.

A. Capella and C. A. Salgado

Laboratoire de Physique Théorique*

Université de Paris XI, Bâtiment 210, F-91405 Orsay Cedex, France

Abstract

We review the two sources of hyperon enhancement in the dual parton model: strings originating from diquark–antidiquark pairs in the nucleon sea and net baryons containing two or three sea quarks with a yield controlled by the observed stopping. We show that adding final state interactions (including strangeness exchange reactions as well as the inverse reactions required by detailed balance) with a single averaged cross-section $\sigma = 0.2$ mb, we can explain the observed hyperon enhancement in PbPb collisions at CERN SPS.

LPT Orsay 00-66

July 2000

*Unité Mixte de Recherche - CNRS - UMR n° 8627

The dual parton model (DPM) is an independent string model. The total number of strings is $2n$ where n is the number of inelastic collisions. When a nucleon undergoes a single inelastic scattering, the two produced strings have only valence constituents (quark and diquark) at their ends. In the case of multiple collisions the extra strings involve sea quarks or diquarks at their ends. We have shown in [1] and [2] that this produces a substantial increase of the ratio of strange over non-strange baryons in AA collisions with increasing centrality. However, this mechanism produces equal enhancement of baryons and antibaryons – in disagreement with experiment. Fortunately, there is another source of hyperon enhancement, which is intimately related to baryon stopping, and enhances only the net hyperon yield $Y - \bar{Y}$. Indeed, large number of net baryons are produced at mid-rapidities in central AA collisions. It has been argued [1]–[5] that they are dominantly made out of the string junction (SJ) (see [6]), which carries the baryon quantum number, plus three sea quarks (see Fig. 1). It is then obvious that a large number of net Λ , Ξ and Ω (i.e. an increase of their yields per participant) will also take place. As a matter of fact, this is the only possibility to produce net Ω 's. The experimental value $\bar{\Omega}/\Omega \sim 0.4$ [7] in central PbPb collisions at mid-rapidities is very much in favour of the above picture. Moreover, there will also be a substantial increase in the yield of K^+ associated to the production of Λ 's.

The two sources of strangeness enhancement described above were studied in detail in refs. [1] and [2]. The numerical results are shown by the dashed lines in Fig. 2. We see that the p and Λ yields are well reproduced. The Ξ 's are slightly underestimated. However, the Ω 's are too low by a factor of 5.

In an attempt to describe the Ω yield, we have introduced in refs. [1] and [2] the

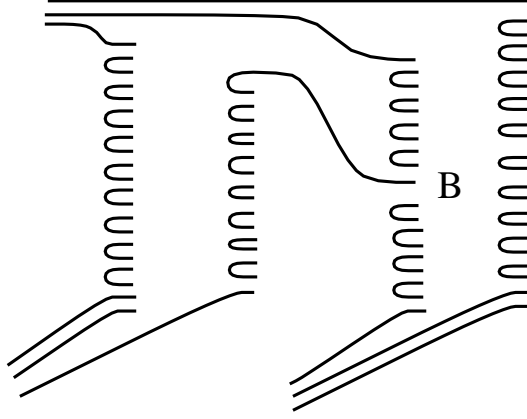


Figure 1: Example of diquark breaking (DB) diagram for net baryon production in pA with two inelastic collisions. The baryon is, in this case, made out of three sea quarks.

final state interactions :

$$\pi N \rightarrow K\Lambda, \pi N \rightarrow K\Sigma, \pi\Lambda \rightarrow K\Xi, \pi\Sigma \rightarrow K\Xi \text{ and } \pi\Xi \rightarrow K\Omega, \quad (1)$$

plus the corresponding reactions for the antiparticles. They are governed by the gain and loss differential equations [9]

$$\frac{dN_i}{d^4x} = \sum_{K,\ell} \sigma_{k\ell} \rho_k(x) \rho_\ell(x) - \sum_k \sigma_{ik} \rho_i(x) \rho_k(x) . \quad (2)$$

The first term in the r.h.s. of (2) describes the production of particle i resulting from the interaction of particles k and ℓ with space-time densities $\rho(x)$ and cross-sections $\sigma_{k\ell}$ (averaged over the momentum distributions of the interacting particles). The second term describes the loss of particle i due to its interaction with particle k . The initial densities are the ones obtained without final state interaction and the averaged cross-sections are taken to be the same for all processes. For details see [1].

Proceeding in this way, we were able to reproduce the observed enhancement of all hyperon species [1, 2]. However, in our approach we neglected the inverse

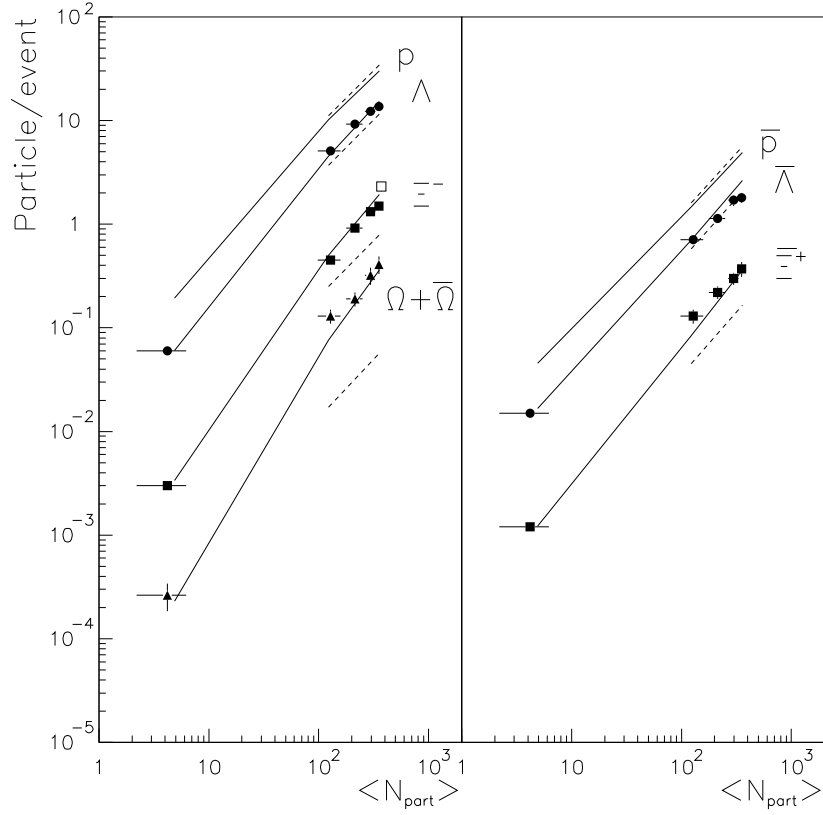


Figure 2: Yields of p , Λ , Ξ^- , $\Omega + \bar{\Omega}$, \bar{p} , $\bar{\Lambda}$ and $\bar{\Xi}^+$ for minimum bias pPb (158 GeV/c) and central $PbPb$ collisions (158 AGeV/c) in four centrality bins. Experimental data are from WA97 [7] (black points) and NA49 [8] (open square). Dashed lines are our results before final state interaction and full lines are the results including this final state interaction.

reactions, which are required by detailed balance, as well as the charge exchange reactions:

$$\pi\Lambda \rightleftharpoons KN, \pi\Sigma \rightleftharpoons K\Lambda, \pi\Xi \rightleftharpoons K\Lambda, \pi\Xi \rightleftharpoons K\Sigma, \text{ and } \pi\Omega \rightleftharpoons K\Xi. \quad (3)$$

together with the corresponding ones for antiparticles.

Although the possibility to neglect such reactions was qualitatively justified using the relative size of the initial densities involved [1, 2, 10], this was considered to be

a crucial drawback of our model [11]. In view of that, we have now introduced all these reactions. For simplicity we use a single value for all averaged cross-sections $\sigma_{kl} = \sigma$. The results with $\sigma = 0.2$ mb are shown by the full lines of Fig. 2. We see that the agreement with experiment is satisfactory.

The reason why the introduction of the new reactions has produced no substantial change in our former results is the following: concerning the non strangeness enhancement reactions (inverse of those in (1)) such as $K\Lambda \rightarrow \pi N$, it is obvious that since $\rho_K < \rho_\pi$ and $\rho_\Lambda < \rho_N$ one has $\rho_K \rho_\Lambda \ll \rho_\pi \rho_N$, and the effect of these reactions is very small (of course, if the interaction time would be much larger than the 6 fm measured from Bose-Einstein interferometry, the inverse reactions would be crucial). For the strangeness exchange reactions (3) such as $\pi\Omega \rightarrow \bar{K}\Xi$, the situation is different. If we compare this reaction with $\pi\Xi \rightarrow K\Omega$, the former is disfavored since $\rho_\Xi > \rho_\Omega$. However, since Ω 's are strongly enhanced, the effect of the former might be important – and would destroy Ω 's. Actually, it turns out that the effect of this reactions is only moderate. Moreover, the inverse reaction $\bar{K}\Xi \rightarrow \pi\Omega$ turns out to be of comparable importance and restores the yield of Ω 's obtained without the strangeness-exchange reactions (3).

In conclusion, we have shown that the dual parton model, supplemented with final state interactions (both with and without strangeness exchange) describes the observed enhancement of hyperon and antihyperon yields with a single value of the averaged cross-sections – which turns out to be rather small: $\sigma = 0.2$ mb.

Acknowledgments

It is a pleasure to thank N. Armesto, J. A. Casado, E. G. Ferreira, U. Heinz, A. B. Kaidalov, C. Pajares and J. Tran Thanh Van for discussions. A.C. acknowledges

partial support from a NATO grant OUTF.LG 971390. C.A.S. thanks Ministerio de Educación y Cultura of Spain for financial support.

References

- [1] A. Capella and C. A. Salgado, Phys. Rev. **C60**, 054906 (1999).
- [2] A. Capella, E. G. Ferreira and C. A. Salgado, Phys. Lett. **B459**, 27 (1999).
- [3] D. Kharzeev, Phys. Lett. **B378**, 238 (1996).
- [4] S. E. Vance and M. Gyulassy, Phys. Rev. Lett. **83**, 1735 (1999)
- [5] A. Capella and B. Kopeliovich, Phys. Lett. **B381**, 325 (1996).
- [6] G. C. Rossi and G. Veneziano, Nucl. Phys. **B123**, 507 (1977).
- [7] WA97 collaboration : E. Andersen et al, Phys. Lett. **B433**, 209 (1998); Phys. Lett. **B449**, 401 (1999).
- [8] NA49 collaboration : H. Appelshäuser et al, Phys. Lett. **B444**, 523 (1998).
- [9] B. Koch, U. Heinz and J. Pitsut, Phys. Lett. **B243**, 149 (1990).
- [10] A. Capella, Acta Phys. Polon. **B30**, 3541 (1999)
- [11] U. Heinz, Nucl. Phys. **A661**, 140 (1999)